

CONSTRAINTS TO AGRICULTURAL MECHANIZATION IN ETHIOPIA: THE CASE OF SOLAR IRRIGATION PUMPS

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Ethiopia's agricultural machinery sector suffers from both supply- and demand-side challenges. Strengthening equitable cluster farming, machinery services, irrigation technology supply chains, the appropriate sizing of machinery, and innovative financing are possible complementary entry points to strengthen mechanization in the country.

AGRICULTURAL MECHANIZATION IN ETHIOPIA

Agriculture and food production in Ethiopia are dominated by smallholder farmers and characterized by a low input-low output system. Mechanization of agriculture—in particular, the widespread adoption of tractors for land preparation and motorized pumps for irrigation—is considered by many to be the key to breaking this low-productivity system. Agricultural mechanization can improve the livelihoods of smallholders by reducing drudgery and postharvest losses and by increasing the efficiency of farm operations. However, mechanization rates have increased only slowly in Sub-Saharan Africa.

Mechanization has largely bypassed smallholder farmers in some of the largest agriculture-dominated countries on the subcontinent, such as Ethiopia. Ayele (2021) notes that this is due to: perceived land and labor abundance; prioritization of mechanization for larger, commercial farms; a delayed, partial smallholder mechanization strategy that focuses on tractors and not mechanized irrigation; and the lack of an enabling environment for a private sector-led mechanization industry.

While the potential for mechanized irrigation is substantial and the government is supporting irrigation development, the share of irrigated area in total crop area has increased only slowly and is currently at 5–7 percent of crop area (NBE 2023). A recent study noted farmers' preferences for motorized pumps over manual, pulley and rope and washer technologies. Mechanized pumps are more efficient and labor saving, but farmers face financial constraints to access them (Tesfaye, Balana, and Bizimana 2021). Given the limited access to electricity in rural Ethiopia, most farmers rely on diesel pumps. However, in May 2023, the Ministry of Irrigation and Lowlands announced it would end the importation of diesel- and petrol-based motor pumps and replace them with pumps using renewable energy resources, such as solar irrigation pumps (ESI 2023). While Ethiopia has had a Solar Energy Development Association ([EDESA](#)) since 2009, bringing solar-powered irrigation pumps (as well as diesel and petrol pumps) into the country has been challenging, largely due to a restrictive foreign exchange regime. Other challenges affecting the irrigation supply chain include: lengthy importation processes; a challenging tax exemption system; poor-quality irrigation technologies in the market; and a lack of spare parts (Teferi et al. 2024).

The main objective of this policy note is to highlight the constraints to mechanization in Ethiopia as experienced by farmers, directly focusing on mechanized irrigation, and particularly on solar-powered irrigation. Based on these experiences, we develop pathways to accelerate mechanization with a focus on sustainability and equity considerations, drawing on survey results and the literature. The analysis brings together the International Food Policy Research Institute and [Power for All Ethiopia](#) which supports the rural energy transition in the country and forms part of the NEXUS Gains transdisciplinary rural energy transition portfolio.

The analysis is based on nonrepresentative survey data collected from 600 smallholder farmers in Amhara, Oromia, Sidama, SNNP (Southern Nations, Nationalities and People's),¹ and Southwest Ethiopia regions. Surveyed farmers are those who recently agreed to participating in cluster farming and are awaiting mechanization access and farmers in similar, adjacent sites that are not part of agricultural cluster plans. Farmers who join cluster farming link up their farmland to achieve economies of scale for agricultural inputs, including mechanization, and for better linkages with markets. Studies suggest that cluster farming is associated with improved market linkages and commercialization (Dureti, Tabe-Ojong, and Owusu-Sekyere 2023). The survey data cover mechanization practices, irrigation development, and farmers' perceptions around mechanized agriculture and were collected between July 2023 (Oromia, Sidama, SNNP, and Southwest Ethiopia) and February 2024 (Amhara). The survey also included a separate module that asked about services and challenges in each of the participating communities. This module was answered by knowledgeable community leaders or members.

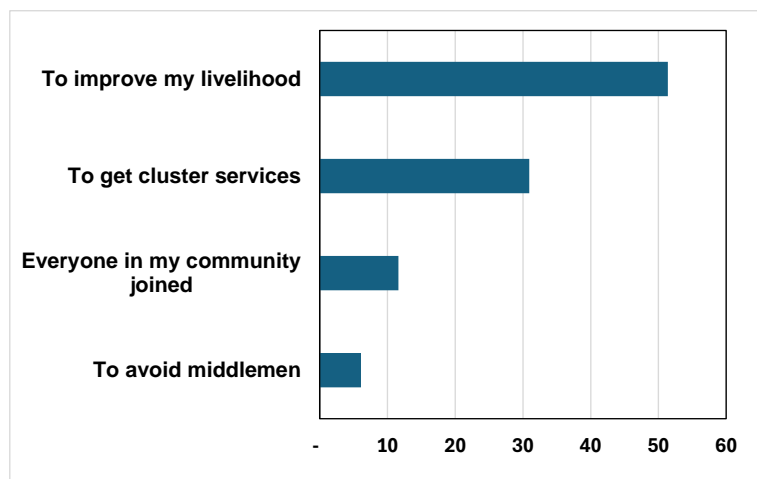
Strong desire for mechanization among farmers

With cluster farming considered an important entry point for mechanization, farmers participating in the clusters under development were asked about their reasons for participation. Slightly more than one-half (51 percent) of farmers inside the

clusters responded that the key reason was to improve their livelihood; close to one-third joined to access cluster services; and smaller shares noted as the main reason for participation that everyone else in the community was joining (12 percent) and avoidance of middlemen (6 percent).

Nineteen percent of the sampled farmers irrigate at least one of their plots, primarily using surface water. Of these, 12 percent use mostly diesel-powered pumps to lift water, mostly in Amhara region. Farmers consider diesel pumps to have high direct and indirect costs; direct costs include the high price of diesel, while indirect costs include fuel supply shortages, long distances to acquire fuel (as fuel stations are usually only found in urban areas), and high fuel price volatility. Electric- and solar-powered pumps could address these challenges but are currently not accessible. Only one farmer in the sample operates an electric pump. Given limited access to and

Figure 1 Reason for joining cluster farming



Source: Authors.

low quality of the electric grid, solar-powered pumps stand out as the only currently viable option for smallholder farmers to achieve economic and some environmental objectives.

However, around 80 percent of the sample respondents were not aware of solar-powered irrigation pumps (Table 1). Despite lack of awareness, 60 percent of these farmers were interested in purchasing such a pump if they could. This reflects farmers' strong desire for mechanized irrigation. Among the small share of farmers with great familiarity, an equal 60 percent were interested in acquiring a solar-powered pump. Among farmers with interest, 57 percent would prefer individual ownership, 29 percent ownership with relatives or other farmers, and the remainder sharing through a water user association.

¹ SNNP region was a standalone region during our survey but has since been split into Central Ethiopia Regional State and South Ethiopia Regional State.

Table 1: Knowledge level of solar-powered irrigation pumps

Knowledge level	Share (%)	Interested in buying at this knowledge level (%)
Not at all	80	60
Very little - I have heard of them but do not know how they work	16	76
Average - I know the technology and I know how they work	3	69
Very aware - I know the technology, I know how they work and how to operate them	2	60

Source: Authors.

Large challenges around accessing solar-powered pumps

Respondents who indicated no interest in acquiring a solar-powered pump highlighted three major obstacles: lack of access to water sources; lack of access to solar pumps; and lack of solar pump affordability. These three challenges are interrelated and directly linked with the low awareness of solar-powered pumps. With a focus on surface water resources among irrigators in this sample—only 12 percent are lifting water—lack of surface water access might well be equated with lack of water access. Motor pumps can lift water from invisible, underground water resources, even in areas at a considerable distance from surface water resources. As such, greater pump access can also increase access to water resources, although well drilling is costly (Balasubramanya et al. 2024). Lack of water was also noted in the community-level survey that accompanied individual farmer surveys, particularly in Oromia and SNNP (Table 2).

Table 2: Community-level data on electricity access, cluster farming, and irrigation challenges (%)

Description	Amhara	SNNP	Sidama	Southwest	Oromia
Access to the electric grid	90	38	21	0	100
Cluster farming available	9	8	17	33	50
Major challenges in irrigation					
• Lack of irrigation machinery	28	17	62	56	
• Lack of fuel for powering irrigation pumps	4	17	7	11	
• Lack of repair service for irrigation pumps	4		4		
• Lack of water	52	67	21	33	100
• Conflict among irrigation water users	11				
• Conflict between irrigators and other water users (domestic/livestock)	2				

Source: Authors.

Even for farmers with access to finance, motor pumps cannot be easily accessed. Machinery suppliers have established their distribution centers in regional capitals, requiring time and resources to purchase pumps. At the same time, farmers do not have sufficient information about solar-powered pumps, where to find them, their cost, and technical and practical specifications. Information channels are needed that narrow the distance between technology suppliers and users. Such channels also need to match farmer realities with available products. Otherwise, farmers might well purchase over- or undersized pumps, or low-quality solar panels that have a short lifespan and high maintenance needs. Extension services do not currently cover mechanization options. In the community survey, lack of access to irrigation machinery was particularly noted in Sidama and the Southwest regions (Table 2).

Moreover, financial constraints affect local production, imports, and uptake of agricultural mechanization. Lack of foreign exchange (Deribe et al. 2021) and administrative challenges limit importation of machinery, accessories, and spare parts. This is compounded by the pronounced lack of access to credit among the sampled farmers: 71 percent of farmers noted that they had no access. After-sales maintenance and spare parts were not listed as major obstacles, likely because motor pump ownership is low in the sample. Formal financial schemes (banks and microfinance) require collateral for borrowing, while informal systems, such as farmer cooperatives, cannot lend the amounts needed to purchase solar-powered pumps. At the same time, farmers are generally not willing to use collateral (if they have any) for technologies they are not familiar with (Chavas and Nauges, 2020).

Pathways to mechanization

Mechanization requires tailored and scalable solutions that are accessible to poorer farmers and ensure the sustainability of agricultural production systems. We suggest more support for cluster farming, machinery services, irrigation technology supply chains, the appropriate sizing of machinery, and innovative financing as possible complementary ways to address the above constraints.

Support equitable cluster farming

According to the survey data, farmers who joined clusters largely did so to improve their livelihoods and to get access to mechanization and other services. Clusters, by exerting scale economies, can more easily access inputs, including machinery that is not suited to smaller plots. However, important questions arise around farmers' autonomy following their joining of lands in clusters. Can farmers opt out if they do not agree with the production systems imposed by cluster farms or if their expected income increases do not materialize? To what extent are farmers consulted in cropping, marketing, and input decisions? If farmers retain agency and can influence management decisions in cluster farming and if access to resources improves, then this is an important pathway to solarization and other mechanization.

Strengthen machinery service provision

Accessing machinery services is an alternative to owning machinery and is closely linked with the cluster farming model in Ethiopia. A lot of machinery is too large and expensive for smallholder farmers and most machinery is only used for several days, weeks, or months in a year. In such cases, purchasing machinery services—including for planting, irrigating, harvesting, and postharvest processing—allows smallholder farmers or groups of farmers to access technology that can increase productivity and farmer incomes. Service providers can more easily overcome investment, maintenance and appropriate sizing challenges than smallholder farmers by purchasing machinery in bulk at a discount, by offering different types and sizes of machinery and by concentrating knowledge on maintenance and repair in a single location. Machinery service provision can also open additional employment provision in rural areas. At the same time, machinery services are affected by the same supply chain challenges as private machinery acquisition, and they typically face significant start up constraints.

Improve irrigation technology and other machinery supply chains

Supply chains need to be dramatically improved for farmers to gain access to solar-powered pumps and other machinery. The Government of Ethiopia exempts agricultural mechanization, irrigation, and animal feed technologies and equipment from import duties. All solar products are, moreover, exempted from value-added tax. However, implementation of these policies has been challenging (Teferi et al. 2024). Value chains are further hampered by the government's restrictive for-

exchange policy, making it difficult for machinery importers to hold accounts in US\$, which are needed to pay for imports (Deribe et al. 2021). Supply chains can also be strengthened by supporting domestic production of agricultural machinery. National demand is large enough and Ethiopia has been successful in attracting foreign direct investment in other areas. A national production base would also ease access to accessories and spare parts, and would increase strategic autonomy and resilience during shocks.

Support appropriate sizing of machinery

Connections between suppliers and buyers of machinery should be strengthened in ways that improve equity in access to and sustainability of machinery. As an example, oversized solar-powered pumps are too expensive for smallholder farmers and could lead to groundwater depletion, while undersized pumps affect farm profitability. Smallholder farmers, moreover, tend to purchase poor-quality solar panels that, while cheaper, have reduced lifespans and efficiency. Solar-sizing is also closely linked to the depth of the water table (or need for water lifting), the cropping pattern, and climatic variables; they jointly determine the volume of water that needs to be lifted. Appropriate machinery sizing is also important for other machinery, such as postharvest machinery and tractors. Stronger linkages between farmers and machinery suppliers can ensure that farmers' feedback, including that of women farmers, is incorporated into machinery design and offers. It should be in agro-dealers' interest to understand the systems preferred by farmers and the challenges they face during use. The NEXUS Gains initiative is involved in the development of solar-sizing tools in South Asia and Sub-Saharan Africa.

Provide innovative financing

Developing tailored financial solutions that allow farmers to purchase machinery or machinery services is critical to expanding access to and use of machinery in Ethiopia. Business models include cluster farming, where services are provided as part of cluster participation, while finance models can include in-kind payments, pay-as-you harvest, or risk-contingent credit that links lenders with government or grant funding for insurance protection that when triggered transfers part or all of the borrower's liability to the lender. Experiences on financing machinery and machinery services have been developed across low- and middle-income countries, but few models are used in Ethiopia because of the continued bottleneck of getting machinery into the country. More research is needed to understand which models agro-dealers and other intermediaries are willing to try out to broaden their client base.

Concluding remarks

The low level of mechanization in Sub-Saharan Africa, and particularly in Ethiopia, is often attributed to supply-side factors. However, demand-side factors are also important: inadequate demand for tools and equipment affects the growth of local manufacturing and reduces the import volumes of necessary tools and equipment. Ethiopia suffers from both supply- and demand-side challenges, which together contribute to weak mechanization markets for smallholder farmers. Farmers are not aware of available technologies and cannot access affordable finance products, while technology suppliers cannot import technologies suited to smallholder farmers and have no incentives to set up shop in rural communities.

Urgent actions are needed to address these supply- and demand-side impediments. Cluster farming, appropriate machinery sizing, machinery services, improved machinery supply chains, and innovative finance and business models can all contribute in complementary ways to improving the equity and sustainability of machinery access and use. More research is needed to ensure that machinery supports both equity in and sustainability of agricultural production systems.

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This policy note was developed with support of the CGIAR Initiative on NEXUS Gains. It has not been independently peer reviewed. The opinions expressed here belong to the authors, and do not necessarily reflect those of the organizations contributing to the study.

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